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# Magnetic coupling between liquid $^3$He and a solid state substrate: a new approach

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**Abstract**

We suggest a new approach for solving the long-standing problem of a magnetic coupling between liquid $^3$He and a solid state substrate at temperatures above the Fermi temperature. The approach is based on our previous careful investigations of the physical state of a solid substrate by means of several experimental methods (EPR, NMR, conductometry, and magnetization measurements). The developed approach allows, first, to get more detailed information about the magnetic coupling phenomenon by varying the repetition time in pulse NMR investigations of liquid $^3$He in contact with the solid state substrate and, second, to compare the obtained dependences and the data of NMR-cryoporometry and AFM-microscopy. 

*Keywords:* $^3$He normal liquid; Magnetic coupling

## 1. Introduction

A new approach related to investigations of both the magnetism and the structure of a substrate surface has been proposed to solve the long-life problem on the nature of the magnetic coupling between liquid $^3$He and a solid substrate [1–4]. In order to explain the observed large value [1] of relaxation rates of liquid $^3$He in the macroscopic gap between the crystal surfaces of the dielectric Van Vleck paramagnet $LiTmF_4$ and its diamagnetic analog $LiYF_4$ a model for the effect of a restricted geometry (microcracks on the crystal surfaces) on the magnetic relaxation was proposed [1,5]. Paramagnetic defect centers appear on the surfaces of these microcracks as a result of large distortions in the crystal lattice. The properties of these centers were studied in Ref. [3] by EPR, conductometry, NMR of $^{19}$F, and magnetization measurements. In Ref. [4], it was shown that liquid $^3$He can be used as a probe for investigation of the magnetic properties of a solid surface at both low and ultralow temperatures. In the present article, we continue the study of the magnetic relaxation of liquid $^3$He in its contact with a solid substrate — a crystal surface of finely dispersed $LiYF_4$ dielectric powder.

## 2. Transverse relaxation of liquid $^3$He

We have investigated the transverse relaxation of liquid $^3$He in the pores of finely dispersed $LiYF_4$ powder by means of pulse NMR. The spin–spin relaxation in liquid $^3$He is determined both by dipole–dipole interactions between nuclear spins and by interaction with paramagnetic centers on the solid substrate surface. From a general point of view one cannot expect that there exists a dependence of the transverse relaxation time $T_2$ on the pulse sequence repetition time. Nevertheless in our experiments we have determined that, as the repetition time is shorter than the nuclear spin-lattice relaxation time $T_1$ of liquid $^3$He, the transverse relaxation time starts to decrease two times and even more (see

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